A Database Management System for Soil Data and Fertilizer Planning

S. BJARNASON

Department of Soil Science, Swedish University of Agricultural Sciences, Uppsala /SWEDEN/

Introduction

The economic situation of Swedish farmers is strained. To minimize the influence of fertilization on the environment new taxes on fertilizers have been introduced. Reduced use of fertilizer might, however, cause another problem: namely the deterioration of soil fertility. There is, therefore, an increasing need in Swedish agriculture for greater precision in fertilizer application, taking into account both economical, environmental and soil fertility factors.

After many decades of experimentation in the field of soil fertility and plant nutrition, Swedish soil scientists are in possession of a vast amount of knowledge with regard to the effects of various soil factors on optimal fertilization rates. Only factors where the quantitative influence has been very thoroughly examined in a large number of experiments are included in the official fertilizer recommendations /NILSSON, 1989/. For many other factors, however, it is well-known that they have effects on the fertilizer requirement and in what direction /PERSSON, 1989/. A synthesis of existing knowledge has now been made and a new model for optimal fertilizer use has been developed /BJARNASON, 1989/.

Much of the work undertaken during fertilizer planning is repetitive and tedious. Therefore, there certainly is a great deal of scope for using computers to reduce the time spent doing the mundane tasks. When a new and more complicated model is introduced there will be an increased need for a powerful computer system for information handling and for carrying out the calculations.

The new model and a computerized system for fertilizer planning is described below. More detailed information about the model and the computer system is available in a Swedish publication /BJARNASON, 1989/. The working name for the system is PC-Plan.

Organization of data

At the center of any information system is a database. Any collection of related information grouped together as a single item is a database /SIMPSON, 1986/. In a computerized database the information is usually organized and stored in tables /files/ with rows /records/ and columns /fields/. When different tables can be linked together by a common field this is referred to as a relational database.

In PC-Plan the information is stored in a relational database. The system was developed using a programming language included in a commercially available database management system for IBM compatible personal computers. The system includes six different tables of data.

1. *Farms.* This table includes all data that are specific for each farm included in the system, e.g. the farmer's name and address and the animal intensity on each farm /number of animals in relation to the total field size/.

2. *Fields.* Data that are specific for a given farm and field, but which are the same for many years, e.g. humus content and soil type. A field is defined as a part of the farmer's land that is homogeneous enough to be characterized by an average value for all important soil characteristics and is never divided into parts where different crops are grown. The entire field is therefore always fertilized in the same way and makes up the unity for fertilizer planning.

3. *Years.* Data that are specific for each particular year on each field and farm, e.g., which crop/variety is grown and the type and amount of animal manure added. These three tables are available for the user of the system to add, modify and delete data. Tables 4 through 6 are used in the calculations and are only partly available for the user.

4. *Crops.* In this file there is one record for each crop and variety considered, and the different fields contain different information used in the calculations, e.g. average N requirement, and P and K% in the yield. The data cannot be changed by the user.

5. *Manure.* Here, different types of animal manure make up the record and the different fields contain data for the amount of available nutrients /N, P and K/ for each type. If the amount of nutrients has been analyzed, the user can introduce his own values in the table. The user can also add to the table any types of organic manure not considered by the program in its state as delivered.

6. *Fertilizers.* The different types of fertilizer available in Sweden are listed together with the price and the amount of nutrients. The user can add additional types of fertilizers and mark the fertilizers he does not want to use.

Fertilizer planning

After the data have been registered in tables /files/ 1 and 2, the fertilizer planning in PC-Plan can be divided into three steps.

1. For each crop the selected crop/variety is registered together with the expected yield.

2. For those fields receiving animal manure, the type of manure, the amount and the time of application /fall or spring/ are registered.

3. The program is then run for calculation of N, P and K requirement.

If the results of step 3 indicate that better use of the nutrients in the manure can be made by altering the plan of manure application, the user can return to step 2.

The calculations in step 3 proceed as follows:

1. For each crop grown, the average N need, P% and K% in the yield product is obtained from table /file/ 4.

2. The expected yield is used to adjust the N requirement and to calculate P and K removal. For sugarbeets and potatoes the amount of P removed is based on both the amount in beats and tubers and in the green residues; for other crops only the yield product is considered.

3. The N requirement is adjusted for crop grown in the previous year, residue treatments and the winter weather or, if measurements are available, mineral N. The N requirement is also adjusted for N mineralization during the growing period, which is estimated from the animal intensity on the farm and the soil humus content.

4. P requirement is calculated by multiplying the estimated P removal by a P-factor that depends on crop and soil type, amount of easily soluble P according to the Swedish AL-method /SVENSSON, 1989/ and pH /Table 1/.

5. Similarly, K requirement is calculated by multiplying the estimated K removal by a K-factor that depends on crop and soil type, AL-K and HCl-K /Table 2/.

6. The P and K requirements are adjusted to the excess P and K added in the previous year. In these calculations K excess is dependent on residue treatments for all crops, P in sugarbeet and potato residues is also supposed

Table 1

Influence of AL-P and root depth on P-factor

AL-P topsoil	AL-P subsoil	Root depth, cm 60	90	120
V	V	0.1	0.0	0.0
	IV	0.3	0.2	0.1
	III	0.5	0.4	0.3
	II	0.7	0.6	0.5
	I	0.9	0.8	0.7
IV	V	0.6	0.5	0.4
	IV	0.8	0.7	0.6
	III	1.0	0.9	0.8
	II	1.2	1.1	1.0
	I	1.4	1.3	1.2
III	V	1.1	1.0	0.9
	IV	1.3	1.2	1.1
	III	1.5	1.4	1.3
	II	1.7	1.6	1.5
	I	1.9	1.8	1.7
II	V	1.6	1.5	1.4
	IV	1.8	1.7	1.6
	III	2.0	1.9	1.8
	II	2.2	2.1	2.0
	I	2.4	2.3	2.2
I	V	2.1	2.0	1.9
	IV	2.3	2.2	2.1
	III	2.5	2.4	2.3
	II	2.7	2.6	2.5
	I	2.9	2.8	2.7

Table 2

Influence of AL-K and root depth on K-factor

AL-K topsoil	AL-K subsoil	Root depth, cm 60	90	120
V	V	0.0	0.0	0.0
	IV	0.1	0.0	0.0
	III	0.5	0.2	0.0
	II	0.9	0.6	0.3
	I	1.3	1.0	0.7
IV	V	0.2	0.0	0.0
	IV	0.6	0.3	0.0
	III	1.0	0.7	0.4
	II	1.4	1.1	0.8
	I	1.8	1.5	1.2
III	V	0.7	0.4	0.1
	IV	1.1	0.8	0.5
	III	1.5	1.2	0.9
	II	1.9	1.6	1.3
	I	2.3	2.0	1.7
II	V	1.2	0.9	0.6
	IV	1.6	1.3	0.9
	III	2.0	1.7	1.4
	II	2.4	2.1	1.8
	I	2.8	2.5	2.2
I	V	1.7	1.4	1.1
	IV	2.1	1.8	1.5
	III	2.5	2.2	1.9
	II	2.9	2.6	2.3
	I	3.3	3.0	2.7

to be available for the next crop. If pH is not optimal, then not all the excess P is considered to be available for the next crop.

7. In the last step the amount of available N, P and K in manure is subtracted from the N, P and K requirement to get the fertilizer requirement. The program then seeks through the fertilizer file to find the cheapest combination of two fertilizers /or just one/ that fulfills the N, P and K requirement. If there is an excess of P and K, the amounts are stored in the year file to be used in the calculations in the next year. The program summarizes the amount of different fertilizers needed and the total costs.

Conclusions

The model presented here is an extension of the official fertilizer recommendations in Sweden. Many of the model parameters are derived from basic research and have not been tested in traditional field research. This is the case for the effects of root depth on the P- and K-factors presented in this paper /HAAK, 1981/. Another example is the effects of animal intensity on N mineralization. In a pilot work, N mineralization has been found to be higher on farms with high animal intensity than on farms without animals.

Due to the complexity of the plant/soil system one cannot expect to get statistically significant results in field experiments for all soil factors and interactions between soil factors and between soil and plant factors. It is, therefore, my opinion that a fertilization model should be based on a synthesis of all available knowledge about the system. Such a model is also necessary for the research work in this field. The model hypothesis can then be used as a platform for research work with more defined objectives.

The use of computers to carry out the calculations needed in fertilizer planning should be without question.

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